AD-272 422

MEDICAL RESEARCH LABORATORY

U. S. Naval Submarine Base
New London

Vol. XII, No. 6 | REPORT NO. 221 | 30 Mar. 1953

THE SUITABILITY OF SUBMARINE COMPRESSED AIR FOR USE IN THE SUBMARINE ESCAPE APPLIANCE

by

C. P. Yaglou

and

V. F. Borum

Bureau of Medicine and Surgery, Navy Department
Project NM 002 015.08.02

THE SUITABILITY OF SUBMARINE COMPRESSED AIR FOR USE IN THE SUBMARINE ESCAPE APPLIANCE

by

C. P. Yaglou, CDR, USNR*

and

V. F. Borum, LT JG, MC, USN

Medical Research Laboratory Report No. 221

Bureau of Medicine and Surgery, Navy Department
Project NM 002 015.08.02

Released by

Gerald J. Duffner
Commander, MC, U. S. Navy
Officer-in-Charge
U. S. Naval Medical Research Laboratory
30 March 1953

*This study was performed during a two-week training duty period.

ABSTRACT

Analysis of compressed air from the banks of ten submarines of various types operating in the New London area during the month of February 1953 showed a normal composition of respiratory gases, and only sub-threshold traces of contaminants, contributed largely by compressor oils.

From the standpoint of purity, the submarine service air appeared to be entirely suitable as a respiratory medium for use in the submarine escape appliance at great depths.

THE SUITABILITY OF SUBMARINE COMPRESSED AIR FOR USE IN THE SUBMARINE ESCAPE APPLIANCE

INTRODUCTION

The breathing of pure oxygen from the Submarine Escape Appliance, (also known as the Momsen "lung"), during submarine escape operations involves grave danger of oxygen poisoning, even at relatively shallow depths. As a result of studies at the Experimental Diving Unit, it has been recommended that compressed air from the high-pressure banks of submarines be used as a breathing medium for charging the lung in making escapes from depths of 150 feet or greater, provided that the air is free of noxious substances (1).

The problem of air vitiation assumes paramount importance in respiration at high pressures. Traces of toxic gases in the air, that have little or no effect when breathed at atmospheric pressure, may render the air unsuitable for respiration when their partial pressure is increased by compression at great depths.

The purpose of the work to be described herein was to ascertain whether submarine compressed air contains any toxic substances in concentrations that would make it unsuitable for respiration at depths as great as 300 feet, (10 atmospheres absolute), from which escapes might be attempted with an air-filled escape appliance.

METHODS OF AIR SAMPLING AND ANALYSIS

Samples of compressed air were withdrawn into large flasks from the banks of ten (10) submarines operating in the New London area. The flasks were then taken to the laboratory for sampling and analysis for the following substances: Oxygen (O_2), Carbon Dioxide (CO_2), Carbon Monoxide (CO), Hydrogen Sulphide (H_2S), Arsine (AsH_3), Stibine (SbH_3), aldehydes, dusts, oil vapors and odors.

Since, in all of the submarines studied, the air was compressed from the engine room, or pump room, where traces of noxious gases might be expected to exist, an analysis was also made of the Submarine Base service air (yard air) as a control. This air is compressed directly from the weather air, and presumably is vitiated only by the compressors.

Oxygen and carbon dioxide concentrations were determined by the Scholander microanalytical method (2). For carbon monoxide a Mine Safety Appliance CO tester was used, capable of detecting concentrations as low as five parts per million parts of air (p.p.m.)

Screening tests for hydrogen sulfide were made by the lead acetate paper method. Strips of filter paper freshly impregnated with a solution of one per cent lead acetate in five per cent acetic acid, were held in a jet of compressed air from the sampling flasks for as long as 20 minutes. Failure to obtain a stain on the lead acetate paper indicated the absence of H_2S and obviated the need for more elaborate analytical procedures. The lowest detectable concentration by this method is placed at 0.1 p.p.m. approximately.

Screening tests for stibine and arsine were carried out in a manner similar to that used for H_2S, by impregnating strips of filter paper with a solution of one per cent silver nitrate. Failure to produce a stain indicated absence of SbH_3, or AsH_3, as well as of H_2S and PH_3 which also react, if present, with the silver nitrate in the test paper. Specific tests for AsH_3 were performed in a few instances by bubbling the air samples through a solution of cuprous chloride to remove H_2S, SbH_3 and PH_3, before contacting the silver nitrate test paper. The sensitivity of this test paper to color development is about 0.2 p.p.m. for stibine.

Aldehydes were absorbed in dust-free distilled water by passing the compressed air through a standard Greenburg impinger at a rate of 1 c.f.m. for from two and a half to three hours. Concentrations were determined colorimetrically by mixing fluid from the impinger with equal parts of Schiff's reagent (3). The color developed by the reagent was then compared with freshly prepared formaldehyde color standards, using a Klett-Summerson Colorimeter for reading color intensity.

Dust particles were counted in undiluted impinger samples by means of a Spenser "Bright-Line" Haemacytometer using a conventional light field counting system with 10 X objective and 30 X eyepiece (4).

Oil vapors were collected by passing the compressed air through oil-free silica gel at a rate of one half L.p.m. for from two and a half to three hours. The oils were then extracted with a known volume of carbon tetrachloride and compared for fluorescence under a "dark lamp" with standards made of S.A.E. No. 30 petroleum lubricating oil in carbon tetrachloride at concentrations as low as 1.4×10^{-3} mg.oil/gm CCl_4[1]

Odors. In the absence of an objective method for quantitating odors in air, reliance lead to be placed upon olfactory sensations, which were graded as (1) neutral, (2) perceptible, (3) moderate or acceptable, (4) strong, (5) very strong, and (6) overpowering or nauseating.

RESULTS

There seemed to be no significant difference in composition between air compressed from the engine rooms of submarines and the Submarine Base service air compressed from weather air (see Table 1.). Oxygen and carbon dioxide concentrations were within normal limits. The few low CO_2 values shown were ascribed to the insensitivity of the Scholander apparatus at low concentrations. A definite but insignificant trace of CO appeared only in the air from the banks of the USS CONGER. In all other instances, tests were negative, showing that if any CO were present at all its concentration would have been less than the minimum detectable by the analytical method used (i.e. less than 5 p.p.m.). In the absence of CO, no tests for methane were made.

Small quantities of aldehydes were detected in the air from the banks of the USS CORSAIR and USS TORSK, as well as in the Base service air. The aldehydes found presumably represented products of thermal decomposition of compressor oils, rather than products of diesel engine exhaust, or distilation of fats in the galley, that are readily soluble in water. The characteristic pungent odor of acrolein or formaldehyde was lacking.

All tests for H_2S, AsH_3, and SbH_3 were negative with reference to limits of detectability by the analytical methods used (Table 1). H_2S, being highly soluble in water, normally would be removed along with the condensate when the banks are periodically blown off. This also holds true of chlorine, if accidentally present, and to some extent of sulphur dioxide and sulphur trioxide from the Diesel engines, if the fuel contains appreciable amounts of sulphur.

Arsine is a powerful nerve and blood poison, and may be formed during the charging of batteries by the action of sulfuric acid on arsenic that might be present as an impurity in the battery grid material.

Stibine, like arsine, is a highly toxic gas attacking the blood and the central nervous system. It is formed in small amounts during the overcharging of batteries by the action of nascent hydrogen on the lead-antimony compounds used in battery grids. The quantity produced increases with the age of batteries. Occurrence of SbH_3 in the general submarine atmosphere has been reported (5) in instances in which the battery gases were vented into the engine room, but seldom when vented outboard through the main induction valve.

It is unlikely that SbH_3 could exist in the compressed air banks for any length of time. The gas is unstable; it is oxidized by air even at low temperatures, and is readily decomposed by most oxidizing agents. The evidence available indicates complete absence of SbH_3 in the banks of the submarines studied.

The dust content of submarine service air compares favorably with that found in clean and quiet rooms of ordinary buildings.

Oil vapors, too, appeared in such low concentrations as to be of little or no physiological significance (Table 1). Petroleum lubricating oils are not considered dangerous. Men working at grinding machines in industry are daily exposed to dense mists of mineral cutting oils, with no apparent effects other than possible dermatitis due largely to chlorination of petroleum oils for cutting purposes.

All of the air samples had a characteristic rank smell resembling that of rancid castor oil which in itself is strong enough to mask any weaker odor present. Although the smell in the first few breaths was disagreeable or even repulsive to one unaccustomed to compressed air odors, olfactory adaptation rapidly diminished the sensation to within tolerable limits (see Table 1). Personnel accustomed to submarine odors had no objection whatever to breathing the air. The odor was intensified by bubbling the compressed air through distilled dust-free water, but was completely stopped by passing it through activated silica gel which adsorbed all of the oil vapors.

Prolonged breathing of the raw compressed air for periods of from 30 to 40 minutes at atmospheric pressure, or for ten minutes under an equivalent pressure of 165 feet of water (six atmospheres absolute) inside a recompression chamber, caused no respiratory irritation or any other subjective symptoms. At the high pressure, the characteristic oil smell was almost completely absent.

The least amount of odor was found in the air from the banks of the USS K-1, the only submarine of this type tested. Although this may be a mere matter of chance, it should be pointed out that the K-1 is a comparatively new ship equipped with Worthington compressors, instead of the Hardy-Tynes compressors used on the fleet and guppy types of ships, and the compressor suction is located in the Pump Room instead of in the Engine Room. Battery ventilation is by the individual cell system instead of the open well system used in some of the older ships.

DISCUSSION

In the absence of maximum allowable concentrations (M.A.C.) for noxious gases specifically applying to submarine operations, we can turn to industrial standards for comparison of results under the worst possible conditions which might be implied in Table 1. This was done at the bottom of the table by assuming (a) that all noxious gases existed in concentrations approaching the minimal detectable amounts, (b) that the toxicological effects of gases increase linearly with absolute pressure, and (c) that the maximum depth from which escapes might be attempted with an air-filled breathing apparatus is 300 feet (ten atmospheres absolute).

Despite these stern assumptions, the comparison is quite reassuring, allowing, as it does, a wide margin of safety in concentrations as well as in exposure times. Actually, problems of nitrogen narcosis and possible oxygen toxicity would limit the exposure at full pressure to the minimum time required to flood down the escape chamber, and the total time of pressure breathing to not more than ten minutes.

Additional safety features are, incidentally, provided by the carbon dioxide absorber of the Submarine Escape Appliance, capable of removing oil vapors, dusts and some of the noxious gases, if present.

It was not possible to ascertain whether the banks tested contained any vitiated air pumped in during periods of revitalization of the submarine atmosphere, or whether they were charged only with air from the surface. Commanding officers of ships could not answer these questions positively. Some of the banks had not been charged for at least several days, while a few were charged within 24 hours before sampling.

Although storage of air in the banks may result in self purification, as has been previously discussed, it is obviously advantageous to reserve, whenever feasible, at least one clean bank for respiratory purposes, by charging it only with air from the surface when the Diesel engines are not operating. The cooler the bank, the greater will be the tendency for self purification of air.

CONCLUSION

No harmful contaminents were found in submarine service air that would affect its suitability for respiration in conjunction with the Submarine Escape Appliance at great depths.

REFERENCES

1. BuShips Restr. Ltr SS/S94(588) Ser 588-1848 to CO Med. Res. Lab., NewLondon SubBase, 5 Dec 1952

2. Scholander, P.F., The Review of Scientific Instruments, Am. Inst. of Physics, 13, 27, 1942.

3. Snell, F.D. and Snell, C.T., Colorimetric Methods of Analysis, Vol. 2, D. Van Nostrand Co., Inc., NY. 1937

4. Williams, C.R., Jr., Ind. Hyg. Toxicol., 19, 226, 1939

5. Neal, P.A.; Fairhall, L.T.; Webster, S.H.; Liljegren, E.J.: Stibine as a Health Hazard in Submarines: (1) Toxicity and (2) Method of Analysis in Air - BuMed Research Div. Project No. X-166 (Sub. 25), Report No. 3, 3 Aug 1943, Report No. 4, 19 Jun 1944, Report No. 5, 23 May 1945.

ACKNOWLEDGMENTS

Grateful appreciation is expressed to the Commanding Officer of the Submarine Base and Commanding Officers of vessels for their splendid cooperation in making this study possible; to JAMES, W. W., HMC USN and MEGO, J. L., HMC USN for valuable assistance in the preparation of reagents and respiratory gas analysis, and to Dr. L. Silverman, Dr. R. Dennis, and Mr. R. Thomson of the Harvard School of Public Health for carrying out specialized analyses for toxic gases.

TABLE 1. - ANALYSIS OF COMPRESSED AIR FROM THE BANKS OF TEN SUBMARINES IN THE NEW LONDON AREA.
9 FEB to 19 FEB 1953

Air samples from banks of		O_2	CO_2	CO	Aldehydes as CH_2O	H_2S	AsH_3	SbH_3	Dust Particles	Oil Vapc
Name (No.)	Type*	%	%	ppm	ppm	ppm	ppm	ppm	per cf.	mg n
Base service air		20.5	0.02	<5	0.01	<0.1	<0.2	<0.2	8x10⁴	<0.
TUSK (SS426)	(G-2)	20.6	0.03	<5	-	<0.1	<0.2	<0.2	-	-
DIABLO (SS479)	(F)	-	-	<5	-	<0.1	<0.2	<0.2	-	-
CONGER (SS477)	(F)	20.9	0.02	5	<0.01	<0.1	<0.2	<0.2	$12x10^4$	0.
CORSAIR (SS435)	(F)	20.6	0.05	<5	0.30	<0.1	<0.2	<0.2	$12x10^4$	0.
HALFBEAK (SS352)	(G-2)	20.7	0.05	<5	<0.01	<0.1	<0.2	<0.2	$13x10^4$	0.
TIRANTE (SS420)	(G-2A)	20.3	0.01	<5	<0.01	<0.1	<0.2	<0.2	$5x10^4$	0.
K-1 (K-1)		20.5	0.01	<5	<0.01	<0.1	<0.2	<0.2	$9x10^4$	0.
PIPER (SS409)	(S)	20.1	<.01	<5	<0.01	<0.1	<0.2	<0.2	$16x10^4$	<0.
COD (SS224)	(F)	19.8	<.01	<5	<0.01	<0.1	<0.2	<0.2	$6x10^4$	0.
TORSK (SS423)	(S)	20.1	<.01	<5	0.10	<0.1	<0.2	<0.2	$69x10^4$	0.
Mean all submarines		20.4	<.02	<5	<0.06	<0.1	<0.2	<0.2	$18x10^4$	0.
Estim'd at 10 atm.abs.		20.4	<.02	<50	<0.60	<1.0	<2.0	<2.0	$180x10^4$	7.
M.a.c. 1 hr. exposure		-	5 %	400	20	100	3	3	$10000x10^4$	non
M.a.c. 8 hrs. daily		-	0.5	100	5	20	0.05-1.0	0.1-1.0	$5000x10^4$	al

< = less than
* G = Guppy K = Killer
F = Fleet S = Snorkel

1 = neutral
2 = perceptil
3 = Moderate